

## **Growth and Phenomenology of Phytoplankton Thin Layers in the Gulf of Maine**

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### **LONG-TERM GOALS**

Our overarching long-term goal is to understand what controls phytoplankton distribution, optical properties and production in the coastal ocean. Our project-specific goals were to understand the mechanisms responsible for the creation, maintenance and demise of subsurface phytoplankton layers in the Gulf of Maine and to determine the vertical distribution of toxigenic species of *Alexandrium* in the Gulf of Maine.

### **OBJECTIVES**

The primary objectives of the past year's work were: 1) to continue to analyze data from the 2005 and 2006 field programs in the Gulf of Maine to better understand how the subsurface distributions of phytoplankton and suspended particles are controlled by light, nitrate and density structure over a broad range of hydrographic conditions and to understand how distributions of toxigenic species of *Alexandrium* in the Gulf of Maine are related to the overall distribution of bulk phytoplankton and hydrographic properties and 2) to prepare results for publication.

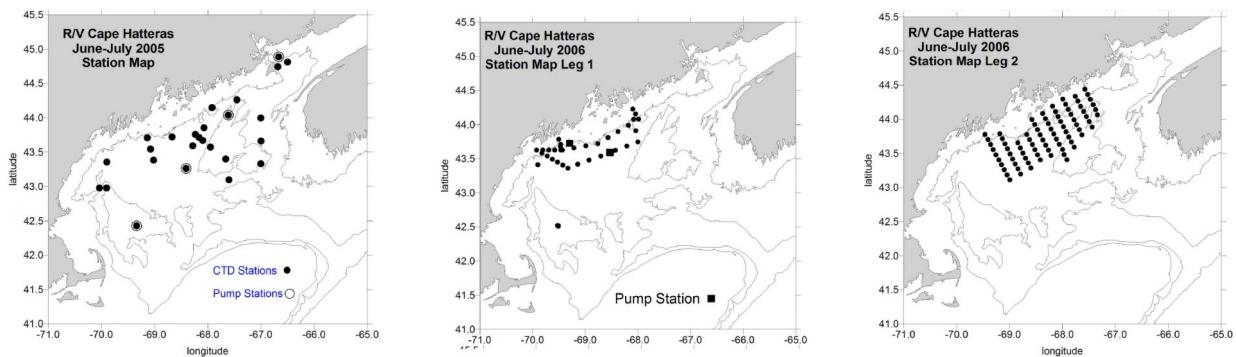
### **APPROACH**

The field program in the Gulf of Maine consisted of two cruises in late June–early July, one each in 2005 and in 2006 on the *R/V Cape Hatteras* and two glider deployments in 2006. A cruise of opportunity in summer 2008 (GOMTOX program) provided some additional data. The field program generated rich data sets of optics and hydrography, including continuous nitrate profiles, and *Alexandrium* distributions.

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The shipboard measurements included CTD profiles with chlorophyll fluorescence, beam transmission, optical backscattering, CDOM fluorescence, ISUS nitrate and dissolved oxygen. Water samples were collected for measurement of extracted chlorophyll, inorganic nutrients, dissolved oxygen, variable fluorescence, particulate and absorbed absorption coefficients, and Lugols-preserved phytoplankton for species composition and abundance (Lugols-preserved). In 2006, high-resolution vertical pump samples were used to collect samples for phytoplankton (especially *Alexandrium fundyense*), chlorophyll and nutrients. In 2006 a Slocum glider was instrumented with a SBE CTD, Aanderaa optode, and two WET Labs Eco pucks (chlorophyll *a* and CDOM fluorescence; 3 wavelengths of optical backscattering) to do two repeat transects of the Eastern Maine Coastal Current.

In the 2005 field program we successfully located phytoplankton thin layers in the Gulf of Maine, but we were not able to stay within a single layer. In the 2006 field year we broadened out approach to a more general study of the vertical structure of subsurface phytoplankton layers in the Gulf of Maine, and carried out a survey program in order to encounter a wide range of optical and hydrographic conditions within a relatively restricted geographic area (Figure 1). In 2008, CTD profiles were collected during a cruise of opportunity.



**Figure 1. Stations sampled during the 2005 (left) and the two legs of the 2006 cruises (Leg I, center, and Leg II, right)**

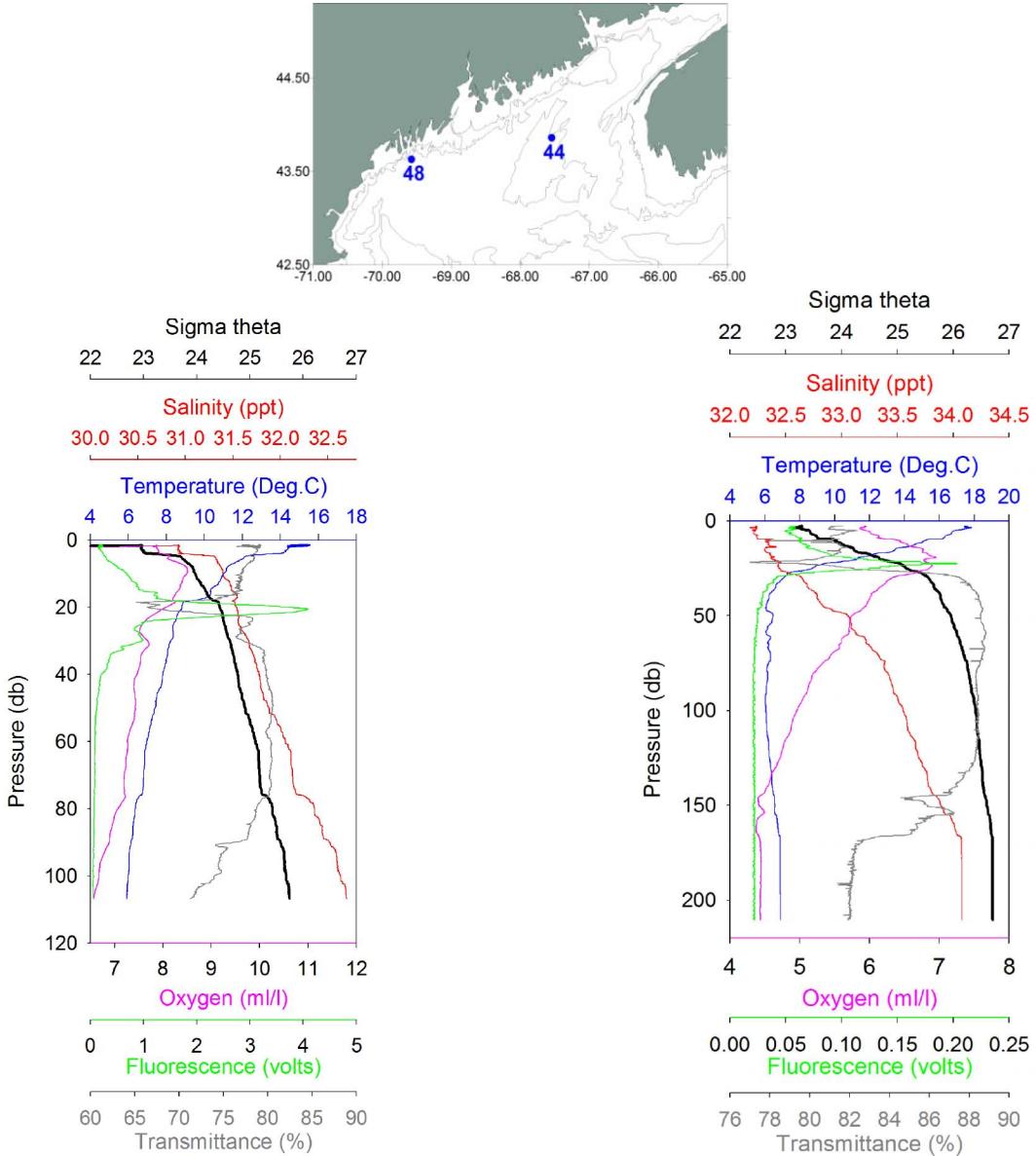
## WORK COMPLETED

In the past year, during our no-cost extension, the work has primarily on processing the phytoplankton samples and preparing manuscripts for publication. All samples have been processed including counts of *Alexandrium fundyense* samples and other Lugols-preserved phytoplankton samples. The nutrient data collected and processed on the two *R/V Cape Hatteras* cruises are being incorporated into Nathan Rebuck's Ph.D. thesis, which concerns the general topic of nutrient dynamics in the Gulf of Maine.

## RESULTS

We routinely observed at most stations a subsurface maximum in phytoplankton chlorophyll fluorescence that roughly coincided with a light transmission minimum. These observations were similar to those reported earlier for the Gulf of Maine (e.g., King et al., 1987; Townsend et al., 1984). An example profile from the 2008 cruise of opportunity in the Gulf of Maine (GOMTOX Program) is presented in Figure 2. More pronounced thin layers were observed in late summer. It appears that

these layers become more pronounced later in the stratified season, although their coincidence with a discernable pycnocline is not obvious in all cases. Nonetheless, we observed that the subsurface maximum in phytoplankton chlorophyll fluorescence was usually associated with secondary (deeper), less pronounced, density gradients than the main seasonal thermocline/pyncnocline throughout most of the Gulf of Maine.

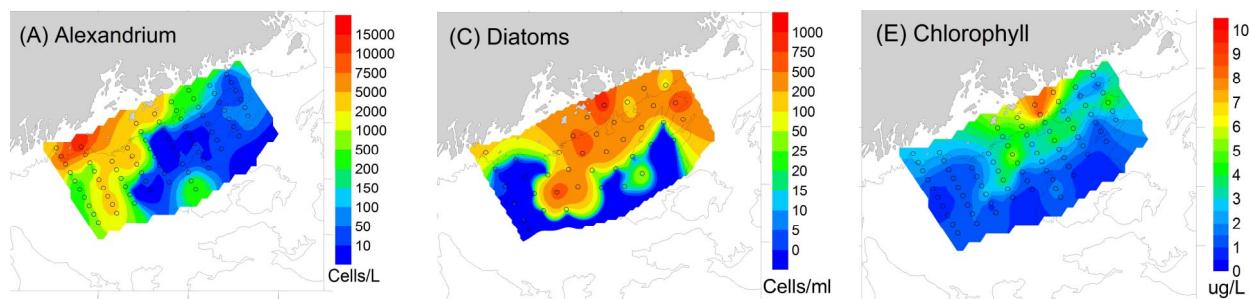


**Figure 2.** Vertical profiles of  $T$ ,  $S$ , density anomaly, dissolved oxygen, phytoplankton chlorophyll fluorescence and light transmission, at stations shown on chart of Gulf of Maine in upper panel. Lower panel, left, is Station 44 in June 2006 and lower panel, right is Station 48 in August 2008.

We also observed that the deep water particle maximum layer, which has been reported earlier in the Gulf of Maine (Townsend and Cammen, 1985; Spinrad, 1986; Townsend et al., 1992) and which occurs at the slight density interface between two deep water masses (Maine Intermediate Water and

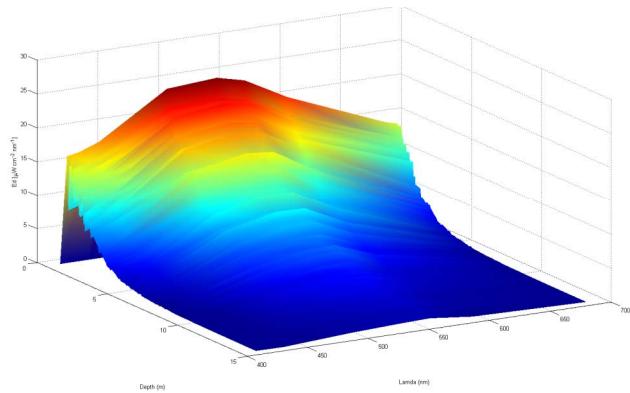
Maine Bottom Water) at depths ranging from ca. 50-100 m above the bottom, was notably absent at most stations occupied in 2005 and 2006. Those layers were observed, however, at many of our deeper stations sampled in August of 2008.

Details of the phytoplankton cell counts are being prepared for publication (see manuscripts listed in “Publications”, below), which includes also results of our nutrient and chlorophyll measurements. We found an inverse distributional relationship between diatoms and dinoflagellates, including the red tide dinoflagellate, *Alexandrium fundyense*, which, in addition to laboratory culture experiments conducted as part of our GOMTOX work, strongly suggest an allelopathic interaction between diatoms and *Alexandrium* (Figure 3). Those results are presently being prepared for publication.



**Figure 3. Distributions of *Alexandrium* spp., diatoms and total chlorophyll concentration..**

A second Slocum glider instrumented with 7-channel upward and downward looking radiometers was deployed in coastal Gulf of Maine in late autumn 2007. Figure 3 shows an example of downwelling irradiance spectra as a function of depth; data are interpolated from 7 wavebands. Only data from the up-glide are collected, due to sensor presentation and geometry.



**Figure 4. Spectral downwelling irradiance, as a function of depth from the surface to 30 m.**

## **IMPACT/APPLICATIONS**

A better understanding of the interaction of hydrography, nutrients, and light in controlling the subsurface distribution of phytoplankton is important to the Navy in its goal of predicting and understanding how biota affect the optical properties of operational importance to the Navy.

## **RELATED PROJECTS**

The underwater glider was acquired under award N000140510412 to Perry, Townsend and colleagues, entitled “Acquisition of Underwater Gliders for Autonomous Sampling in the Gulf of Maine”. Field data in 2008 were collected by Townsend during NOAA sponsored ECO-HAB GOMTOX cruises.

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Perry, M. J. and others. Vertical gradients of nitrate and phytoplankton in the Gulf of Maine. (Manuscript in preparation).

Rebuck, N., D.W. Townsend, K. Smith and M.A. Thomas. A Nutrient Climatology for the Gulf of Maine – Georges Bank Region. (Manuscript in preparation).

Townsend, D.W. L.Karp-Boss, M.A. Thomas, and R. Gettings. Field and Laboratory Evidence of Alleopathic Interactions Between Diatoms and the Toxic Dinoflagellate, *Alexandrium fundyense*, in the Gulf of Maine (Manuscript in preparation).